lab-8-rachit

May 7, 2025

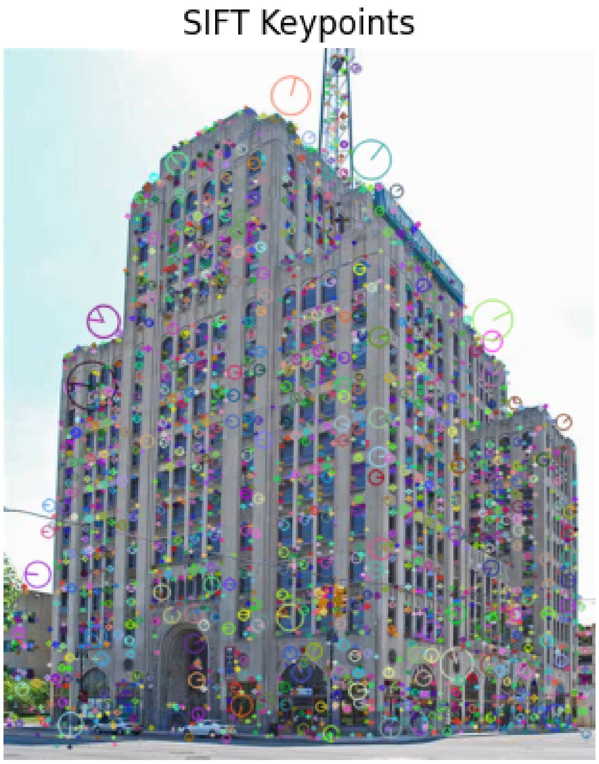
[ ]:

```
pip install opencv-python opencv-contrib-python
```

```
Requirement already satisfied: opencv-python in /usr/local/lib/python3.11/dist-
packages (4.11.0.86)
Requirement already satisfied: opencv-contrib-python in
/usr/local/lib/python3.11/dist-packages (4.11.0.86)
Requirement already satisfied: numpy>=1.21.2 in /usr/local/lib/python3.11/dist-
packages (from opencv-python) (2.0.2)
```

[ ]:

```
import cv2
import matplotlib.pyplot as plt

# Load image
img = cv2.imread('image2.jpeg')
gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

# Create SIFT detector
sift = cv2.SIFT_create()

# Detect keypoints and descriptors
keypoints, descriptors = sift.detectAndCompute(gray, None)

# Draw keypoints
img_sift = cv2.drawKeypoints(img, keypoints, None, flags=cv2.
 ↪DRAW_MATCHES_FLAGS_DRAW_RICH_KEYPOINTS)

# Display
plt.imshow(cv2.cvtColor(img_sift, cv2.COLOR_BGR2RGB))
plt.title('SIFT Keypoints')
plt.axis('off')
plt.show()
```

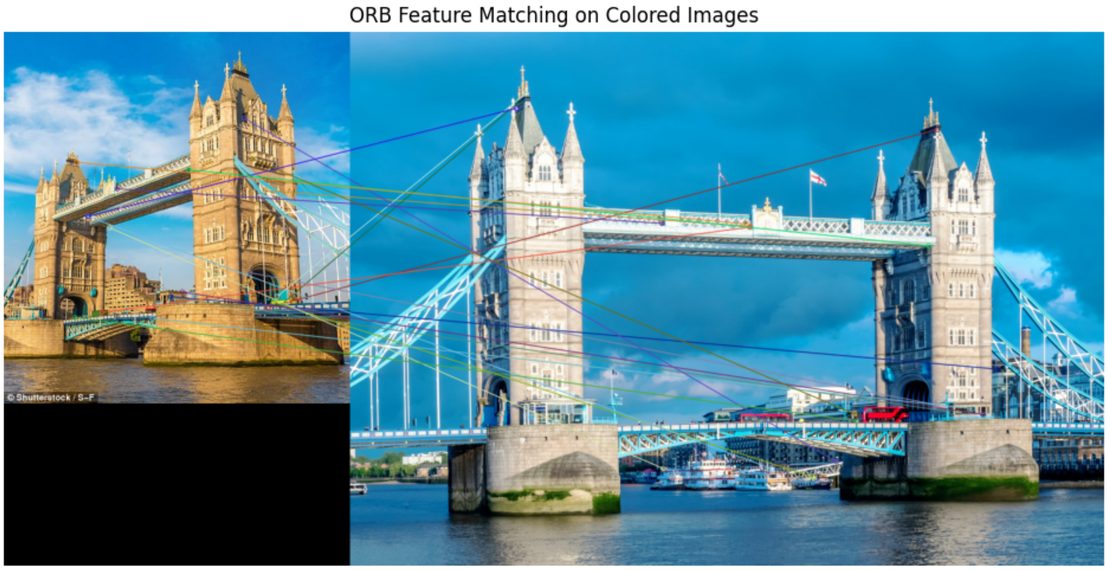


SIFT Keypoints

[ ]:

```python
import cv2
import matplotlib.pyplot as plt

# Load images in color
img1_color = cv2.imread('image3.jpg', cv2.IMREAD_COLOR)
img2_color = cv2.imread('image4.jpg', cv2.IMREAD_COLOR)

# Also convert to grayscale for ORB detection
img1_gray = cv2.cvtColor(img1_color, cv2.COLOR_BGR2GRAY)
img2_gray = cv2.cvtColor(img2_color, cv2.COLOR_BGR2GRAY)

# ORB detector
orb = cv2.ORB_create()

# Find keypoints and descriptors
kp1, des1 = orb.detectAndCompute(img1_gray, None)
kp2, des2 = orb.detectAndCompute(img2_gray, None)

# Create BFMatcher object
bf = cv2.BFMatcher(cv2.NORM_HAMMING, crossCheck=True)

# Match descriptors
```

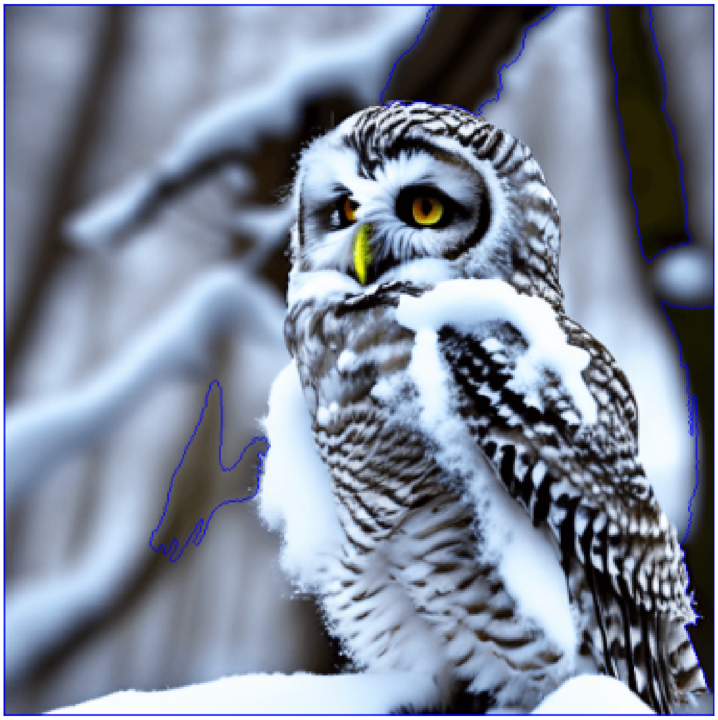
```
matches = bf.match(des1, des2)

# Sort matches by distance
matches = sorted(matches, key=lambda x: x.distance)

# Draw top 20 matches using color images
matched_img = cv2.drawMatches(img1_color, kp1, img2_color, kp2, matches[:20],␣
  ↪None, flags=2)

# Display
plt.figure(figsize=(12, 8))
plt.imshow(cv2.cvtColor(matched_img, cv2.COLOR_BGR2RGB))
plt.title("ORB Feature Matching on Colored Images")
plt.axis('off')
plt.show()
```



[ ]:

```
import numpy as np

# Load image
img = cv2.imread('image7.jpg')
gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

# Convert to binary image
ret, thresh = cv2.threshold(gray, 0, 255, cv2.THRESH_BINARY_INV + cv2.
  ↪THRESH_OTSU)

# Noise removal
kernel = np.ones((3, 3), np.uint8)
```

```
opening = cv2.morphologyEx(thresh, cv2.MORPH_OPEN, kernel, iterations=2)

# Background area
sure_bg = cv2.dilate(opening, kernel, iterations=3)

# Foreground area
dist_transform = cv2.distanceTransform(opening, cv2.DIST_L2, 5)
ret, sure_fg = cv2.threshold(dist_transform, 0.7 * dist_transform.max(), 255, 0)

# Unknown region
sure_fg = np.uint8(sure_fg)
unknown = cv2.subtract(sure_bg, sure_fg)

# Marker labeling
ret, markers = cv2.connectedComponents(sure_fg)

# Add one to all labels so that sure background is not 0
markers = markers + 1

# Mark unknown region as 0
markers[unknown == 255] = 0

# Apply watershed
markers = cv2.watershed(img, markers)
img[markers == -1] = [255, 0, 0]  # mark boundaries in red

# Show result
plt.imshow(cv2.cvtColor(img, cv2.COLOR_BGR2RGB))
plt.title("Contour Detection using Watershed")
plt.axis('off')
plt.show()
```



Contour Detection using Watershed

```
[ ]: import cv2
     import numpy as np
     import matplotlib.pyplot as plt

     # Load the image
     img = cv2.imread('image8.jpg')
     original = cv2.cvtColor(img.copy(), cv2.COLOR_BGR2RGB)  # Convert for␣
      ↪displaying with matplotlib
     gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

     # Thresholding
     ret, thresh = cv2.threshold(gray, 0, 255, cv2.THRESH_BINARY_INV + cv2.
      ↪THRESH_OTSU)

     # Noise removal
     kernel = np.ones((3, 3), np.uint8)
     opening = cv2.morphologyEx(thresh, cv2.MORPH_OPEN, kernel, iterations=2)

     # Sure background and foreground areas
     sure_bg = cv2.dilate(opening, kernel, iterations=3)
     dist_transform = cv2.distanceTransform(opening, cv2.DIST_L2, 5)
     ret, sure_fg = cv2.threshold(dist_transform, 0.7 * dist_transform.max(), 255, 0)
```

```python
sure_fg = np.uint8(sure_fg)
unknown = cv2.subtract(sure_bg, sure_fg)

# Marker labelling
ret, markers = cv2.connectedComponents(sure_fg)
markers = markers + 1
markers[unknown == 255] = 0

# Apply watershed
markers = cv2.watershed(img, markers)

# Create a blank image to color each region
segmented = np.zeros_like(img)

# Assign random colors to each segment
for label in np.unique(markers):
    if label == -1:
        continue
    segmented[markers == label] = np.random.randint(0, 255, size=3)

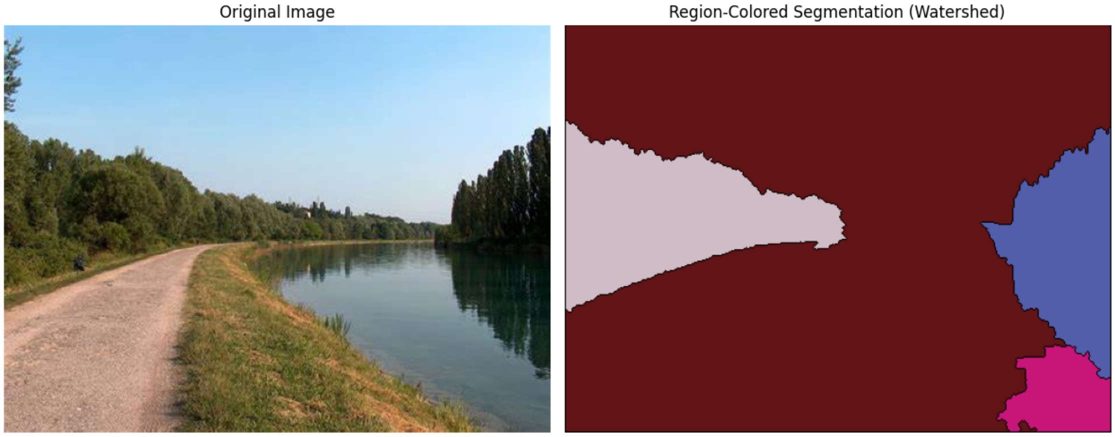
# Convert to RGB for matplotlib
segmented_rgb = cv2.cvtColor(segmented, cv2.COLOR_BGR2RGB)

# Display both original and segmented images
plt.figure(figsize=(12, 6))

plt.subplot(1, 2, 1)
plt.imshow(original)
plt.title('Original Image')
plt.axis('off')

plt.subplot(1, 2, 2)
plt.imshow(segmented_rgb)
plt.title('Region-Colored Segmentation (Watershed)')
plt.axis('off')

plt.tight_layout()
plt.show()
```



Original Image

Region-Colored Segmentation (Watershed)

```
[ ]: !pip install torch torchvision matplotlib tqdm
```

```
Requirement already satisfied: torch in /usr/local/lib/python3.11/dist-packages
(2.6.0+cu124)
Requirement already satisfied: torchvision in /usr/local/lib/python3.11/dist-
packages (0.21.0+cu124)
Requirement already satisfied: matplotlib in /usr/local/lib/python3.11/dist-
packages (3.10.0)
Requirement already satisfied: tqdm in /usr/local/lib/python3.11/dist-packages
(4.67.1)
Requirement already satisfied: filelock in /usr/local/lib/python3.11/dist-
packages (from torch) (3.18.0)
Requirement already satisfied: typing-extensions>=4.10.0 in
/usr/local/lib/python3.11/dist-packages (from torch) (4.13.2)
Requirement already satisfied: networkx in /usr/local/lib/python3.11/dist-
packages (from torch) (3.4.2)
Requirement already satisfied: jinja2 in /usr/local/lib/python3.11/dist-packages
(from torch) (3.1.6)
Requirement already satisfied: fsspec in /usr/local/lib/python3.11/dist-packages
(from torch) (2025.3.2)
Collecting nvidia-cuda-nvrtc-cu12==12.4.127 (from torch)
  Downloading nvidia_cuda_nvrtc_cu12-12.4.127-py3-none-
manylinux2014_x86_64.whl.metadata (1.5 kB)
Collecting nvidia-cuda-runtime-cu12==12.4.127 (from torch)
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Collecting nvidia-cuda-cupti-cu12==12.4.127 (from torch)
  Downloading nvidia_cuda_cupti_cu12-12.4.127-py3-none-
manylinux2014_x86_64.whl.metadata (1.6 kB)
Collecting nvidia-cudnn-cu12==9.1.0.70 (from torch)
  Downloading nvidia_cudnn_cu12-9.1.0.70-py3-none-
manylinux2014_x86_64.whl.metadata (1.6 kB)
```

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Collecting nvidia-cublas-cu12==12.4.5.8 (from torch)
  Downloading nvidia_cublas_cu12-12.4.5.8-py3-none-
manylinux2014_x86_64.whl.metadata (1.5 kB)
Collecting nvidia-cufft-cu12==11.2.1.3 (from torch)
  Downloading nvidia_cufft_cu12-11.2.1.3-py3-none-
manylinux2014_x86_64.whl.metadata (1.5 kB)
Collecting nvidia-curand-cu12==10.3.5.147 (from torch)
  Downloading nvidia_curand_cu12-10.3.5.147-py3-none-
manylinux2014_x86_64.whl.metadata (1.5 kB)
Collecting nvidia-cusolver-cu12==11.6.1.9 (from torch)
  Downloading nvidia_cusolver_cu12-11.6.1.9-py3-none-
manylinux2014_x86_64.whl.metadata (1.6 kB)
Collecting nvidia-cusparse-cu12==12.3.1.170 (from torch)
  Downloading nvidia_cusparse_cu12-12.3.1.170-py3-none-
manylinux2014_x86_64.whl.metadata (1.6 kB)
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/usr/local/lib/python3.11/dist-packages (from torch) (0.6.2)
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/usr/local/lib/python3.11/dist-packages (from torch) (2.21.5)
Requirement already satisfied: nvidia-nvtx-cu12==12.4.127 in
/usr/local/lib/python3.11/dist-packages (from torch) (12.4.127)
Collecting nvidia-nvjitlink-cu12==12.4.127 (from torch)
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manylinux2014_x86_64.whl.metadata (1.5 kB)
Requirement already satisfied: triton==3.2.0 in /usr/local/lib/python3.11/dist-
packages (from torch) (3.2.0)
Requirement already satisfied: sympy==1.13.1 in /usr/local/lib/python3.11/dist-
packages (from torch) (1.13.1)
Requirement already satisfied: mpmath<1.4,>=1.1.0 in
/usr/local/lib/python3.11/dist-packages (from sympy==1.13.1->torch) (1.3.0)
Requirement already satisfied: numpy in /usr/local/lib/python3.11/dist-packages
(from torchvision) (2.0.2)
Requirement already satisfied: pillow!=8.3.*,>=5.3.0 in
/usr/local/lib/python3.11/dist-packages (from torchvision) (11.1.0)
Requirement already satisfied: contourpy>=1.0.1 in
/usr/local/lib/python3.11/dist-packages (from matplotlib) (1.3.2)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.11/dist-
packages (from matplotlib) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in
/usr/local/lib/python3.11/dist-packages (from matplotlib) (4.57.0)
Requirement already satisfied: kiwisolver>=1.3.1 in
/usr/local/lib/python3.11/dist-packages (from matplotlib) (1.4.8)
Requirement already satisfied: packaging>=20.0 in
/usr/local/lib/python3.11/dist-packages (from matplotlib) (24.2)
Requirement already satisfied: pyparsing>=2.3.1 in
/usr/local/lib/python3.11/dist-packages (from matplotlib) (3.2.3)
Requirement already satisfied: python-dateutil>=2.7 in
/usr/local/lib/python3.11/dist-packages (from matplotlib) (2.8.2)
```

```
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.11/dist-
packages (from python-dateutil>=2.7->matplotlib) (1.17.0)
Requirement already satisfied: MarkupSafe>=2.0 in
/usr/local/lib/python3.11/dist-packages (from jinja2->torch) (3.0.2)
Downloading nvidia_cublas_cu12-12.4.5.8-py3-none-manylinux2014_x86_64.whl (363.4
MB)
                          363.4/363.4 MB
3.9 MB/s eta 0:00:00
Downloading nvidia_cuda_cupti_cu12-12.4.127-py3-none-
manylinux2014_x86_64.whl (13.8 MB)
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126.4 MB/s eta 0:00:00
Downloading nvidia_cuda_nvrtc_cu12-12.4.127-py3-none-
manylinux2014_x86_64.whl (24.6 MB)
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100.3 MB/s eta 0:00:00
Downloading nvidia_cuda_runtime_cu12-12.4.127-py3-none-
manylinux2014_x86_64.whl (883 kB)
                          883.7/883.7 kB
41.9 MB/s eta 0:00:00
Downloading nvidia_cudnn_cu12-9.1.0.70-py3-none-manylinux2014_x86_64.whl
(664.8 MB)
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1.0 MB/s eta 0:00:00
Downloading nvidia_cufft_cu12-11.2.1.3-py3-none-manylinux2014_x86_64.whl
(211.5 MB)
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5.9 MB/s eta 0:00:00
Downloading nvidia_curand_cu12-10.3.5.147-py3-none-
manylinux2014_x86_64.whl (56.3 MB)
                          56.3/56.3 MB
13.3 MB/s eta 0:00:00
Downloading nvidia_cusolver_cu12-11.6.1.9-py3-none-
manylinux2014_x86_64.whl (127.9 MB)
                          127.9/127.9 MB
7.5 MB/s eta 0:00:00
Downloading nvidia_cusparse_cu12-12.3.1.170-py3-none-
manylinux2014_x86_64.whl (207.5 MB)
                          207.5/207.5 MB
5.9 MB/s eta 0:00:00
Downloading nvidia_nvjitlink_cu12-12.4.127-py3-none-
manylinux2014_x86_64.whl (21.1 MB)
                          21.1/21.1 MB
37.8 MB/s eta 0:00:00
Installing collected packages: nvidia-nvjitlink-cu12, nvidia-curand-cu12,
nvidia-cufft-cu12, nvidia-cuda-runtime-cu12, nvidia-cuda-nvrtc-cu12, nvidia-
cuda-cupti-cu12, nvidia-cublas-cu12, nvidia-cusparse-cu12, nvidia-cudnn-cu12,
nvidia-cusolver-cu12
```

```
  Attempting uninstall: nvidia-nvjitlink-cu12
    Found existing installation: nvidia-nvjitlink-cu12 12.5.82
    Uninstalling nvidia-nvjitlink-cu12-12.5.82:
      Successfully uninstalled nvidia-nvjitlink-cu12-12.5.82
  Attempting uninstall: nvidia-curand-cu12
    Found existing installation: nvidia-curand-cu12 10.3.6.82
    Uninstalling nvidia-curand-cu12-10.3.6.82:
      Successfully uninstalled nvidia-curand-cu12-10.3.6.82
  Attempting uninstall: nvidia-cufft-cu12
    Found existing installation: nvidia-cufft-cu12 11.2.3.61
    Uninstalling nvidia-cufft-cu12-11.2.3.61:
      Successfully uninstalled nvidia-cufft-cu12-11.2.3.61
  Attempting uninstall: nvidia-cuda-runtime-cu12
    Found existing installation: nvidia-cuda-runtime-cu12 12.5.82
    Uninstalling nvidia-cuda-runtime-cu12-12.5.82:
      Successfully uninstalled nvidia-cuda-runtime-cu12-12.5.82
  Attempting uninstall: nvidia-cuda-nvrtc-cu12
    Found existing installation: nvidia-cuda-nvrtc-cu12 12.5.82
    Uninstalling nvidia-cuda-nvrtc-cu12-12.5.82:
      Successfully uninstalled nvidia-cuda-nvrtc-cu12-12.5.82
  Attempting uninstall: nvidia-cuda-cupti-cu12
    Found existing installation: nvidia-cuda-cupti-cu12 12.5.82
    Uninstalling nvidia-cuda-cupti-cu12-12.5.82:
      Successfully uninstalled nvidia-cuda-cupti-cu12-12.5.82
  Attempting uninstall: nvidia-cublas-cu12
    Found existing installation: nvidia-cublas-cu12 12.5.3.2
    Uninstalling nvidia-cublas-cu12-12.5.3.2:
      Successfully uninstalled nvidia-cublas-cu12-12.5.3.2
  Attempting uninstall: nvidia-cusparse-cu12
    Found existing installation: nvidia-cusparse-cu12 12.5.1.3
    Uninstalling nvidia-cusparse-cu12-12.5.1.3:
      Successfully uninstalled nvidia-cusparse-cu12-12.5.1.3
  Attempting uninstall: nvidia-cudnn-cu12
    Found existing installation: nvidia-cudnn-cu12 9.3.0.75
    Uninstalling nvidia-cudnn-cu12-9.3.0.75:
      Successfully uninstalled nvidia-cudnn-cu12-9.3.0.75
  Attempting uninstall: nvidia-cusolver-cu12
    Found existing installation: nvidia-cusolver-cu12 11.6.3.83
    Uninstalling nvidia-cusolver-cu12-11.6.3.83:
      Successfully uninstalled nvidia-cusolver-cu12-11.6.3.83
Successfully installed nvidia-cublas-cu12-12.4.5.8 nvidia-cuda-cupti-
cu12-12.4.127 nvidia-cuda-nvrtc-cu12-12.4.127 nvidia-cuda-runtime-cu12-12.4.127
nvidia-cudnn-cu12-9.1.0.70 nvidia-cufft-cu12-11.2.1.3 nvidia-curand-
cu12-10.3.5.147 nvidia-cusolver-cu12-11.6.1.9 nvidia-cusparse-cu12-12.3.1.170
nvidia-nvjitlink-cu12-12.4.127
```

[ ]:

```
import torch
import torchvision
import torchvision.transforms as transforms
from torch.utils.data import DataLoader

# Define transformations for normalization and augmentation
transform = transforms.Compose([
    transforms.RandomHorizontalFlip(),
    transforms.RandomCrop(32, padding=4),
    transforms.ToTensor(),
    transforms.Normalize((0.5071, 0.4867, 0.4408), (0.2675, 0.2565, 0.2761))
])

# Load CIFAR-100 dataset
trainset = torchvision.datasets.CIFAR100(root='./data', train=True,␣
 ↪download=True, transform=transform)
testset = torchvision.datasets.CIFAR100(root='./data', train=False,␣
 ↪download=True, transform=transform)

# Define DataLoaders
trainloader = DataLoader(trainset, batch_size=128, shuffle=True, num_workers=2)
testloader = DataLoader(testset, batch_size=100, shuffle=False, num_workers=2)

# Check for GPU availability
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
print("Using device:", device)
```

```
100%|      | 169M/169M [00:07<00:00, 23.6MB/s]
```

```
Using device: cuda
```

[ ]:

```
import torchvision.models as models
import torch.nn as nn

# Load pretrained ResNet models
resnet18 = models.resnet18(pretrained=True)
resnet34 = models.resnet34(pretrained=True)

# Modify the last fully connected layer to match CIFAR-100 (100 classes)
num_ftrs = resnet18.fc.in_features
resnet18.fc = nn.Linear(num_ftrs, 100)
resnet34.fc = nn.Linear(num_ftrs, 100)

# Move models to device
resnet18 = resnet18.to(device)
resnet34 = resnet34.to(device)
```

```
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:208:
```

```
UserWarning: The parameter 'pretrained' is deprecated since 0.13 and may be
removed in the future, please use 'weights' instead.
  warnings.warn(
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:223:
UserWarning: Arguments other than a weight enum or `None` for 'weights' are
deprecated since 0.13 and may be removed in the future. The current behavior is
equivalent to passing `weights=ResNet18_Weights.IMAGENET1K_V1`. You can also use
`weights=ResNet18_Weights.DEFAULT` to get the most up-to-date weights.
  warnings.warn(msg)
Downloading: "https://download.pytorch.org/models/resnet18-f37072fd.pth" to
/root/.cache/torch/hub/checkpoints/resnet18-f37072fd.pth
100%|          | 44.7M/44.7M [00:00<00:00, 189MB/s]
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:223:
UserWarning: Arguments other than a weight enum or `None` for 'weights' are
deprecated since 0.13 and may be removed in the future. The current behavior is
equivalent to passing `weights=ResNet34_Weights.IMAGENET1K_V1`. You can also use
`weights=ResNet34_Weights.DEFAULT` to get the most up-to-date weights.
  warnings.warn(msg)
Downloading: "https://download.pytorch.org/models/resnet34-b627a593.pth" to
/root/.cache/torch/hub/checkpoints/resnet34-b627a593.pth
100%|          | 83.3M/83.3M [00:00<00:00, 147MB/s]
```

[ ]:

```python
import torch.optim as optim
import torch.nn.functional as F
from tqdm import tqdm

# Training function
def train_model(model, trainloader, optimizer, criterion, epochs=10):
    model.train()
    for epoch in range(epochs):
        running_loss = 0.0
        correct = 0
        total = 0

        for inputs, labels in tqdm(trainloader, desc=f"Epoch {epoch+1}/
 ↪{epochs}"):
            inputs, labels = inputs.to(device), labels.to(device)

            optimizer.zero_grad()
            outputs = model(inputs)
            loss = criterion(outputs, labels)
            loss.backward()
            optimizer.step()

            running_loss += loss.item()
            _, predicted = outputs.max(1)
            total += labels.size(0)
            correct += predicted.eq(labels).sum().item()

        print(f"Epoch {epoch+1}: Loss: {running_loss/len(trainloader):.4f},␣
↪Accuracy: {100*correct/total:.2f}%")

# Define loss function and optimizer
criterion = nn.CrossEntropyLoss()

# Train ResNet-18
optimizer18 = optim.Adam(resnet18.parameters(), lr=0.001)
train_model(resnet18, trainloader, optimizer18, criterion, epochs=10)

# Train ResNet-34
optimizer34 = optim.Adam(resnet34.parameters(), lr=0.001)
train_model(resnet34, trainloader, optimizer34, criterion, epochs=10)
```

```
Epoch 1/10: 100%|      | 391/391 [00:22<00:00, 17.19it/s]

Epoch 1: Loss: 3.0017, Accuracy: 25.92%

Epoch 2/10: 100%|      | 391/391 [00:22<00:00, 17.57it/s]

Epoch 2: Loss: 2.2750, Accuracy: 39.41%

Epoch 3/10: 100%|      | 391/391 [00:22<00:00, 17.67it/s]

Epoch 3: Loss: 2.0262, Accuracy: 45.30%

Epoch 4/10: 100%|      | 391/391 [00:21<00:00, 18.15it/s]

Epoch 4: Loss: 1.8646, Accuracy: 48.95%

Epoch 5/10: 100%|      | 391/391 [00:21<00:00, 18.13it/s]

Epoch 5: Loss: 1.7509, Accuracy: 51.52%

Epoch 6/10: 100%|      | 391/391 [00:21<00:00, 17.89it/s]

Epoch 6: Loss: 1.6486, Accuracy: 53.90%

Epoch 7/10: 100%|      | 391/391 [00:22<00:00, 17.66it/s]

Epoch 7: Loss: 1.5678, Accuracy: 55.79%

Epoch 8/10: 100%|      | 391/391 [00:21<00:00, 18.34it/s]

Epoch 8: Loss: 1.4843, Accuracy: 57.49%

Epoch 9/10: 100%|      | 391/391 [00:22<00:00, 17.67it/s]

Epoch 9: Loss: 1.4116, Accuracy: 59.64%

Epoch 10/10: 100%|      | 391/391 [00:22<00:00, 17.58it/s]

Epoch 10: Loss: 1.3652, Accuracy: 60.51%

Epoch 1/10: 100%|      | 391/391 [00:26<00:00, 14.79it/s]
Epoch 1: Loss: 2.9498, Accuracy: 26.52%

Epoch 2/10: 100%|      | 391/391 [00:26<00:00, 14.78it/s]

Epoch 2: Loss: 2.2602, Accuracy: 39.94%

Epoch 3/10: 100%|      | 391/391 [00:26<00:00, 14.88it/s]

Epoch 3: Loss: 1.9401, Accuracy: 47.06%

Epoch 4/10: 100%|      | 391/391 [00:26<00:00, 14.89it/s]

Epoch 4: Loss: 1.8826, Accuracy: 48.41%

Epoch 5/10: 100%|      | 391/391 [00:26<00:00, 14.88it/s]

Epoch 5: Loss: 1.7121, Accuracy: 52.44%

Epoch 6/10: 100%|      | 391/391 [00:26<00:00, 14.85it/s]

Epoch 6: Loss: 1.5873, Accuracy: 55.11%

Epoch 7/10: 100%|      | 391/391 [00:26<00:00, 14.72it/s]

Epoch 7: Loss: 2.0876, Accuracy: 45.20%

Epoch 8/10: 100%|      | 391/391 [00:26<00:00, 14.96it/s]

Epoch 8: Loss: 1.7903, Accuracy: 50.85%

Epoch 9/10: 100%|      | 391/391 [00:28<00:00, 13.95it/s]

Epoch 9: Loss: 1.5354, Accuracy: 56.72%

Epoch 10/10: 100%|      | 391/391 [00:26<00:00, 14.74it/s]

Epoch 10: Loss: 1.6221, Accuracy: 54.89%
```

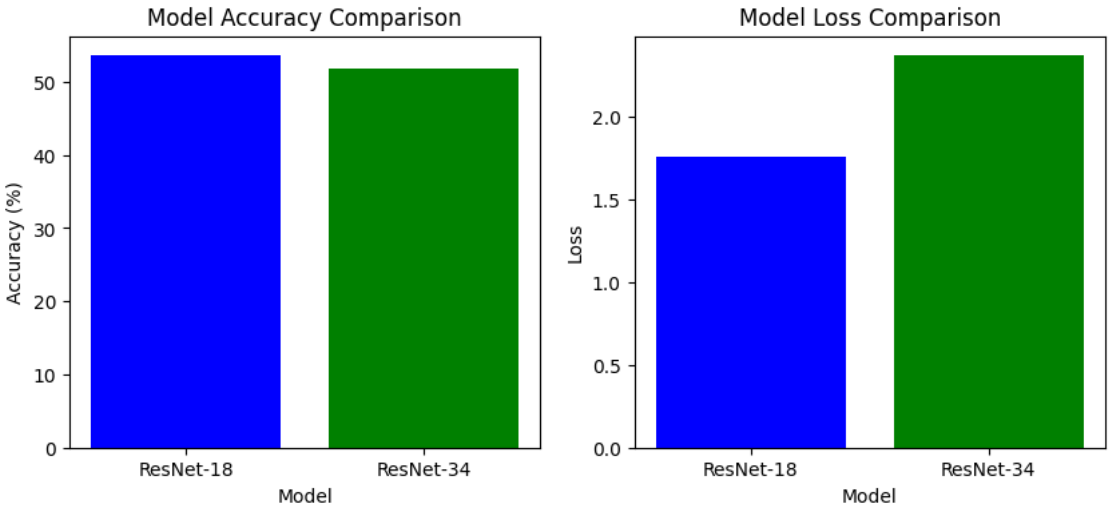
[ ]:

```python
def evaluate_model(model, testloader):
    model.eval()
    correct = 0
    total = 0
    loss = 0.0

    with torch.no_grad():
        for inputs, labels in testloader:
            inputs, labels = inputs.to(device), labels.to(device)
            outputs = model(inputs)
            loss += F.cross_entropy(outputs, labels).item()
            _, predicted = outputs.max(1)
            total += labels.size(0)
            correct += predicted.eq(labels).sum().item()

    accuracy = 100 * correct / total
    loss /= len(testloader)
    print(f"Test Loss: {loss:.4f}, Test Accuracy: {accuracy:.2f}%")
    return accuracy, loss

# Evaluate both models
acc18, loss18 = evaluate_model(resnet18, testloader)
acc34, loss34 = evaluate_model(resnet34, testloader)
```

```
Test Loss: 1.7528, Test Accuracy: 53.56%
Test Loss: 2.3660, Test Accuracy: 51.78%
```

[ ]:

```
import matplotlib.pyplot as plt

models = ["ResNet-18", "ResNet-34"]
accuracies = [acc18, acc34]
losses = [loss18, loss34]

plt.figure(figsize=(10, 4))

# Accuracy plot
plt.subplot(1, 2, 1)
plt.bar(models, accuracies, color=['blue', 'green'])
plt.xlabel("Model")
plt.ylabel("Accuracy (%)")
plt.title("Model Accuracy Comparison")

# Loss plot
plt.subplot(1, 2, 2)
plt.bar(models, losses, color=['blue', 'green'])
plt.xlabel("Model")
plt.ylabel("Loss")
plt.title("Model Loss Comparison")

plt.show()
```



```
[ ]: !pip install torch torchvision numpy scipy
```

```
Requirement already satisfied: torch in /usr/local/lib/python3.11/dist-packages
(2.6.0+cu124)
Requirement already satisfied: torchvision in /usr/local/lib/python3.11/dist-
packages (0.21.0+cu124)
Requirement already satisfied: numpy in /usr/local/lib/python3.11/dist-packages
(2.0.2)
Requirement already satisfied: scipy in /usr/local/lib/python3.11/dist-packages
(1.14.1)
Requirement already satisfied: filelock in /usr/local/lib/python3.11/dist-
packages (from torch) (3.18.0)
Requirement already satisfied: typing-extensions>=4.10.0 in
/usr/local/lib/python3.11/dist-packages (from torch) (4.13.2)
Requirement already satisfied: networkx in /usr/local/lib/python3.11/dist-
packages (from torch) (3.4.2)
Requirement already satisfied: jinja2 in /usr/local/lib/python3.11/dist-packages
(from torch) (3.1.6)
Requirement already satisfied: fsspec in /usr/local/lib/python3.11/dist-packages
(from torch) (2025.3.2)
Requirement already satisfied: nvidia-cuda-nvrtc-cu12==12.4.127 in
/usr/local/lib/python3.11/dist-packages (from torch) (12.4.127)
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/usr/local/lib/python3.11/dist-packages (from torch) (12.4.127)
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/usr/local/lib/python3.11/dist-packages (from torch) (12.4.127)
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/usr/local/lib/python3.11/dist-packages (from torch) (9.1.0.70)
Requirement already satisfied: nvidia-cublas-cu12==12.4.5.8 in
/usr/local/lib/python3.11/dist-packages (from torch) (12.4.5.8)
```

```
Requirement already satisfied: nvidia-cufft-cu12==11.2.1.3 in
/usr/local/lib/python3.11/dist-packages (from torch) (11.2.1.3)
Requirement already satisfied: nvidia-curand-cu12==10.3.5.147 in
/usr/local/lib/python3.11/dist-packages (from torch) (10.3.5.147)
Requirement already satisfied: nvidia-cusolver-cu12==11.6.1.9 in
/usr/local/lib/python3.11/dist-packages (from torch) (11.6.1.9)
Requirement already satisfied: nvidia-cusparse-cu12==12.3.1.170 in
/usr/local/lib/python3.11/dist-packages (from torch) (12.3.1.170)
Requirement already satisfied: nvidia-cusparselt-cu12==0.6.2 in
/usr/local/lib/python3.11/dist-packages (from torch) (0.6.2)
Requirement already satisfied: nvidia-nccl-cu12==2.21.5 in
/usr/local/lib/python3.11/dist-packages (from torch) (2.21.5)
Requirement already satisfied: nvidia-nvtx-cu12==12.4.127 in
/usr/local/lib/python3.11/dist-packages (from torch) (12.4.127)
Requirement already satisfied: nvidia-nvjitlink-cu12==12.4.127 in
/usr/local/lib/python3.11/dist-packages (from torch) (12.4.127)
Requirement already satisfied: triton==3.2.0 in /usr/local/lib/python3.11/dist-
packages (from torch) (3.2.0)
Requirement already satisfied: sympy==1.13.1 in /usr/local/lib/python3.11/dist-
packages (from torch) (1.13.1)
Requirement already satisfied: mpmath<1.4,>=1.1.0 in
/usr/local/lib/python3.11/dist-packages (from sympy==1.13.1->torch) (1.3.0)
Requirement already satisfied: pillow!=8.3.*,>=5.3.0 in
/usr/local/lib/python3.11/dist-packages (from torchvision) (11.1.0)
Requirement already satisfied: MarkupSafe>=2.0 in
/usr/local/lib/python3.11/dist-packages (from jinja2->torch) (3.0.2)
```

[ ]:

```python
import torch
import torchvision
import torchvision.transforms as transforms
from torch.utils.data import DataLoader, random_split

# Define transformation for normalization (Min-Max Scaling)
transform = transforms.Compose([
    transforms.ToTensor(),  # Convert image to tensor
    transforms.Normalize((0.0,), (1.0,))  # Min-Max Scaling (0 to 1)
])

# Load MNIST dataset
trainset = torchvision.datasets.MNIST(root='./data', train=True, download=True,␣
 ↪transform=transform)
testset = torchvision.datasets.MNIST(root='./data', train=False, download=True,␣
 ↪transform=transform)

print(f"Train Dataset Size: {len(trainset)}")
print(f"Test Dataset Size: {len(testset)}")
```

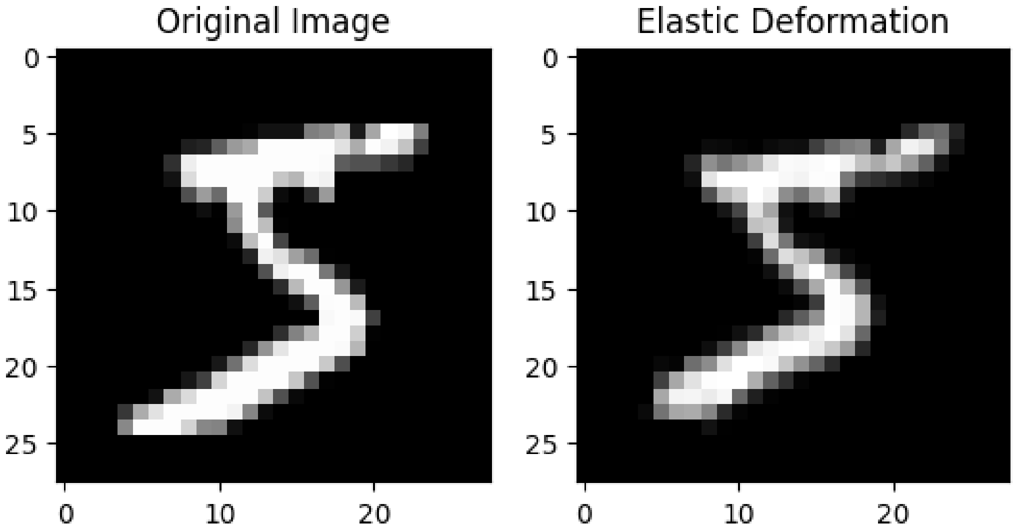
```
100%|      | 9.91M/9.91M [00:00<00:00, 16.0MB/s]
```

```
100%|          | 28.9k/28.9k [00:00<00:00, 490kB/s]
100%|          | 1.65M/1.65M [00:00<00:00, 3.87MB/s]
100%|          | 4.54k/4.54k [00:00<00:00, 7.81MB/s]
```

```
Train Dataset Size: 60000
Test Dataset Size: 10000
```

[ ]:
```python
import numpy as np
import scipy.ndimage

def elastic_transform(image, alpha, sigma):
    """Apply elastic transformation to a single image.

    Args:
    - image: (H, W) numpy array (grayscale image)
    - alpha: Scaling factor for distortion
    - sigma: Standard deviation for Gaussian filter

    Returns:
    - Transformed image as a tensor
    """
    random_state = np.random.RandomState(None)
    shape = image.shape

    # Generate random displacement fields
    dx = scipy.ndimage.gaussian_filter((random_state.rand(*shape) * 2 - 1),␣
  ↪sigma) * alpha
    dy = scipy.ndimage.gaussian_filter((random_state.rand(*shape) * 2 - 1),␣
  ↪sigma) * alpha

    # Create meshgrid and apply distortions
    x, y = np.meshgrid(np.arange(shape[1]), np.arange(shape[0]))
    indices = np.reshape(y + dy, (-1, 1)), np.reshape(x + dx, (-1, 1))

    # Apply transformation
    distorted_image = scipy.ndimage.map_coordinates(image, indices, order=1,␣
  ↪mode='reflect')
    return torch.tensor(distorted_image, dtype=torch.float32).unsqueeze(0)  #␣
  ↪Convert to tensor

# Example of applying elastic transformation
import matplotlib.pyplot as plt

original_img = trainset[0][0].squeeze().numpy()  # Get a sample image
transformed_img = elastic_transform(original_img, alpha=36, sigma=5).squeeze().
  ↪numpy()
```

```
# Plot original and transformed images
transformed_img = transformed_img.reshape(original_img.shape)  # Reshape to 2D

# Plot original and transformed images
fig, ax = plt.subplots(1, 2)
ax[0].imshow(original_img, cmap="gray")
ax[0].set_title("Original Image")
ax[1].imshow(transformed_img, cmap="gray")
ax[1].set_title("Elastic Deformation")

plt.show()
```


Original Image
Elastic Deformation